IP5650-2A

JAPAN · ECONOMIC · INSTITUTE

JEI

REPORT

NO. 9A March 8, 1985

# NEW HORIZONS FOR JAPAN'S NEW MATERIALS INDUSTRY

## Summary

Materials exhibiting unusual characteristics are an increasingly important source of innovative high technology products as well as improved traditional equipment. In Japan and the United States, this applicability to the new and old has attracted attention from long-established companies facing mature markets, such as petrochemical and steel companies, and has nurtured a large number of small, specialized firms. This report will present an overview of Japan's new materials industry and evaluate its strengths in comparison with its U.S. counterpart. The respective roles of the Japanese and U.S. governments will also be examined.

## The Boom in New Materials

The search for improved materials is certainly not new -- man has sought better substances to improve his tools or meet new needs since ancient times, but today's new materials industry is qualitatively different. The cost and time required to develop new materials has skyrocketed as the methodology has changed. The use of state-of-the-art tools has led to leaps in the existing body of knowledge as well as advances into new areas.

The rapid growth of the new materials industry stems from three sources: its wide applicability; the needs of emerging technologies; and advances in molecular physics, supercomputers and laboratory instruments. In addition to making space travel, satellites and high-performance electronic equipment possible, new materials can contribute to a wide range of mundane products,

including home appliances, automobiles, trains, machine tools and so on. Products using new materials often yield better performance to the consumer as well as reduced costs to the manufacturer. The attractions of these materials explains why the critical mass necessary for rapid development was achieved in so short a period of time. Established firms in both countries have played major roles in the industry's growth, but small venture firms can claim credit for equally important contributions. The market is rapidly expanding, providing room for large and small companies to coexist.

Traditional materials, such as steel and aluminum, are being taxed by the demands of high technology because of their inadequate strength-to-weight ratios or limited availability. New materials incorporate characteristics that compare favorably with traditional choices and in some cases are unattainable in those substances. Equally important, they can impart new properties to ordinary materials, opening new markets and leading to new products. The superior energy efficiency of industrial and consumer goods relies increasingly on new materials applications. Some products, such as personal computers and audio equipment, would be impractical or prohibitively expensive if not for recent advances in materials technology. Since both Japan and the United States place a premium on the high technology sector, the new materials industry is viewed as vital to each country's future economic prosperity. It has therefore garnered a large share of the funds devoted to research and development.

The development of new industrial materials used to be a trial-and-error affair based on educated guesswork. Now, however, molecular engineering has advanced to the stage where the guesswork is largely eliminated. Supercomputers and powerful laboratory tools permit researchers to accurately simulate experiments -- increasing the number of runs an individual researcher can perform; reducing the time spent on dead-end paths; and raising the chances of success when real experiments are conducted. The great value of computers derives from their ability to free researchers to ask "what-if" questions and obtain answers quickly and without costly experiments. Errors are quickly uncovered and solutions derived more rapidly using the computer's simulation capabilities. And as researchers have been freed to be more creative and innovative, the rate of discoveries and patent applications has accelerated.

## New Materials: Something for Everyone

New materials can be sorted into seven groups.

Metals - Along with new alloys of common metals, rare metals, once considered of little practical value, are taking center stage. Four general research directions are discernible: improved performance steel, aluminum and other structural metals enhanced by rare-metal alloys; shape memory alloys that alter their physical shape in response to temperature changes; storage alloys that absorb and release other substances in response to environmental changes (hydrogen fuel cells, for example); and amorphous metals, which currently find applications in solar cells and recording heads. Research in shape and storage alloys and amorphous metals is particularly interesting because, unlike the quest for improved structural alloys, the theoretical groundwork is just being laid and the potential is still latent.

The JEI REPORT (ISSN 0744-6489) is published weekly for $40 per year by the Japan Economic Institute of America, 1000 Connecticut Avenue, N.W., Washington, D.C. 20036. Second class postage paid at Washington, D.C. POSTMASTERS: Send address changes to JEI, 1000 Connecticut Avenue, N.W., Washington, D.C. 20036.

Ceramics - Refinements in traditional ceramics techniques as well as raw materials have led to the development of the industry called structural ceramics in this country and fine ceramics in Japan. The attractive properties of ceramics -- good heat conductivity without detrimental effect, low weight, extreme hardness and good corrosion resistance -- have long been known, but only in the past five years have applications beyond dinnerware become possible. By using high-purity powdered ingredients in a rigidly controlled sintering and firing process, complex components can be manufactured that maximize the material's strengths. Ceramic packages for integrated circuits are clearly superior to the plastic counterpart and have gained wide acceptance. Ceramic components are slowly working their way into cars, mostly in areas where heat and corrosive substances quickly wear down metallic parts.

Important problems persist, however. The inherent brittleness of ceramics poses reliability problems in high-vibration environments such as automotive and aircraft engines. As the size and complexity of the component increases, so does the difficulty of assuring consistent quality from current manufacturing techniques. Early predictions of explosive growth and wide acceptance of structural ceramics have been dashed by these problems, but ceramics producers remain confident.

Plastics - The hottest area in new materials centers on a proliferation of plastics with unusual properties. Structural plastics provide the strength of metal and the lightness associated with traditional plastics. The implications in terms of weight and energy efficiency are tremendous; for example, structural plastics could revolutionize the automotive industry. Plastics are well entrenched in the computer industry and could make the jump to wide use in consumer appliances. Traditional plastics have long been employed as electrical insulators, but American and Japanese companies are neck and neck in the race to commercialize plastics that exhibit the opposite quality. Such electroconductive plastics could replace metal wiring and also be molded into equipment cases that shield against electromagnetic interference, both very large potential markets. Finally, specialized plastic membranes, which can separate one constituent element from a mixture, are finding a growing market as the ability of manufacturers to tailor membrane permeability increases. Japanese companies pioneered the use of membranes in desalinization plants, but the competition between researchers around the world to produce membranes permeable to more complex substances remains deadlocked.

The major obstacle to wider use of advanced plastics is their difficult molding characteristics. Large plastic car components are a recent introduction and there are still questions about their long-term performance. Electroconductive plastics are extremely difficult to work with, requiring many processing steps that reduce their cost advantage.

Fibers - Fibers composed of plastic, resin or carbon compounds are increasingly common constituents of aircraft, automotive vehicles and electronic equipment. They are also turning up in such items as bullet-proof vests and lint-free garments for use in ultra-clean semiconductor production facilities. High tensile strength is their greatest selling point, and new uses are being devised continuously.

Composites - While each of the preceding four categories exhibits exceptional qualities individually, they really shine when used in combination

with one another and with other materials. Plastics reinforced with carbon or resin fibers have even better strength-to-weight ratios than advanced structural plastics and also exhibit better wear and impact resistance. Metals fortified with silica, boron or other fibers provide a hybrid: the strength of metal with the flexibility of fibers. In applications such as springs, where all-metal parts fail due to fatigue caused by constant bending, fiber-reinforced metals offer significant performance improvements. Even the unlikely combination of metals and ceramics is being pursued. The U.S. Army's Abrams M-1 main battle tank is sheathed with a steel-fiber-ceramic composite armor that offers unsurpassed penetration resistance and low weight.

Semiconductor makers are looking into bonding metal circuits directly onto a ceramic substrate to increase operating range. High prices resulting from more complex manufacturing processes are the biggest drawback to composites, but researchers are focusing on computer-aided engineering, design and manufacturing techniques to cut the price gap.

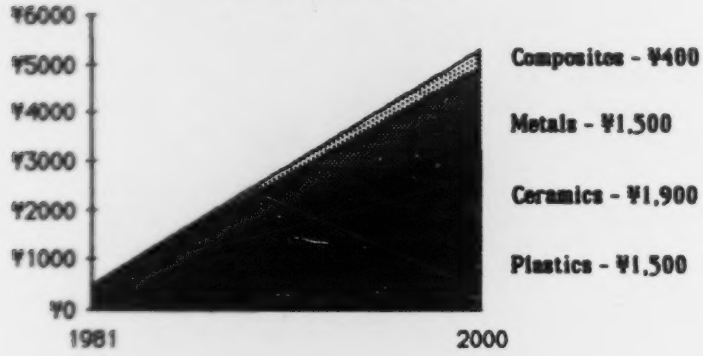
Glass and Crystals - While not as visible as other new materials, glass and crystals made with rare elements offer significant performance improvements in some critical areas. Research into glass panels that reflect heat or radiation is advancing rapidly as is the search for electroconductive glass fibers. If the inherent brittleness of glass can be overcome, the familiar material could show up in surprising places. Crystal technology lies at the heart of the semiconductor industry -- the ability to grow single crystals of silicon is the basis for all integrated circuits. Semiconductor chip technology is rapidly running into the theoretical limitations of silicon, spurring the development of more exotic crystals, such as gallium arsenide (GaAs). Even GaAs-based chips cannot meet the special needs of space vehicles, however, and other combinations are being investigated, including indium phosphide, aluminum arsenide and germanium.

Coatings and Adhesives - Research on coatings runs in two opposite directions: inert coatings and reactive ones. Inert coatings are needed to protect parts from the effects of extreme environments. Coatings that absorb electromagnetic radiation are also gaining increased attention because of their usefulness in electronics and defense applications. Reactive coatings play critical roles in semiconductor manufacturing and in the operation of photocopiers. Resist coatings that have better definition and are easier to use are needed as integrated circuits become more complex. High-speed photocopiers, especially laser printers, rely on fast-reacting light-sensitive compounds to reproduce documents. Researchers are formulating coatings with novel properties in anticipation of new needs.

## The Market Takes Off . . .

According to Japan's Ministry of International Trade and Industry (MITI), the direct market for new materials totaled Y500 billion ($2 billion at Y255=$1.00) in 1981 and could grow to Y5.4 trillion ($21 billion) by the year 2000. Growth rates of 650 percent to 1,400 percent are estimated for the various categories, with the composite market jumping to Y400 billion ($1.6 billion) from zero (see Figure 1). In addition, MITI estimates that the total value of products using new materials and goods related to new materials will reach an impressive Y63 trillion ($247 billion) by the end of this century.

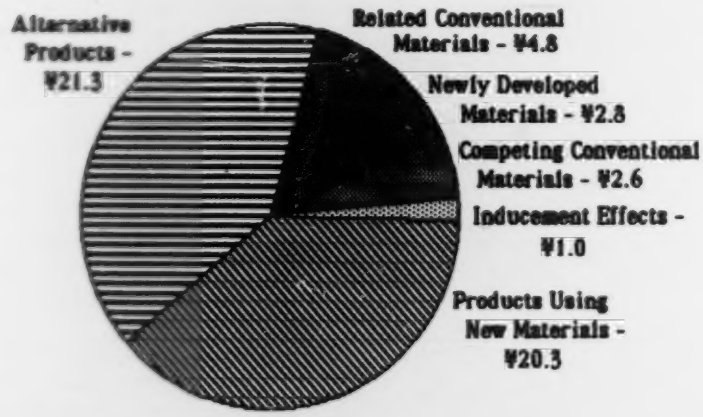
Figure 1: Japan's Projected New Materials Market
(in billions of yen)




Source: Ministry of International Trade and Industry

Beside a Y41.6 trillion ($163 billion) market for products made with new materials, MITI foresees an estimated Y21.4 trillion ($84 billion) market for related products (see Figure 2). MITI's estimates may be conservative -- an advisory body predicts that Japan's annual market for fine ceramics will be in the range of Y2.8 trillion to Y4.2 trillion ($11 billion to $16 billion) by the mid-1990s, and the automotive industry's appetite for structural plastics will certainly be voracious.

Figure 2: Projection for Japan's Total New Materials Market
(in trillions of yen for the year 2000)


Alternative Products - ¥21.3
Related Conventional Materials - ¥4.8
Newly Developed Materials - ¥2.8
Competing Conventional Materials - ¥2.6
Inducement Effects - ¥1.0
Products Using New Materials - ¥20.3

Source: Ministry of International Trade and Industry

Piecemeal estimates for the growth of the U.S. market show equally optimistic outlooks. According to the Society of Plastics Industry, the engineering plastics sector grew 25 percent in 1983 to over $6 billion, and is conservatively estimated to increase between 7 and 8 percent a year for the rest of this century. Plastics are also expected to take a large share of the $400 billion electronics market sometime in the 1990s. The society foresees a tripling of the share of plastics in non-structural car parts from 7 percent to over 20 percent by the late 1990s. Private estimates suggest that the growth of electroconductive plastics may run as high as 58 percent annually by 1988.

. . . With Private Companies in the Lead

The new materials revolution is very much the child of private research, development and commercialization efforts. U.S. and Japanese companies have, in many cases, jumped into new materials by building upon their expertise in traditional materials. Steel, chemical and ceramics firms have drawn from a vast pool of skilled researchers and comprehensive data to capture significant shares of the new market. But small companies have found plenty of room by quickly developing highly specialized products passed over by large firms.

Metals - Japanese companies have mounted strong bids to supply the metal needs of the electronics industry and capture the lead in super-conductive magnetic metals. TDK Corp. has developed an inductor-capacitor chip that relies on ferrite-copper-palladium alloys combined with titanium oxide and barium titanate, a development that could contribute to more compact electric machines.

The production of super-fine metallic powders -- the raw material for many electronic components -- is also a Japanese specialty. Japanese advances in magnetic and optical recording media, such as Hitachi, Ltd.'s silver-zinc and silver-zinc-copper optical media alloys, have been greatly facilitated by super-fine powder technology. American companies and research institutes are turning more frequently to Japan as a powder supplier.

Super magnets are vital to advances in several fields of interest: magnetic locomotion, magnetic fusion reactors and mechanical relays. NEC Corp. has developed an iron-cobalt-manganese magnet that is easier to manufacture but offers performance equal to conventional magnets. Super-conductive magnets for fusion reactors and high-speed trains that operate without wheels are under development at several companies, as are high-output compact magnets for aircraft and machine actuators.

U.S. companies lead in the key area of structural alloys. The Aluminum Co. of America will soon bring on line a plant to produce its aluminum-lithium alloy, which offers aluminum's strength with weight savings of 11 to 15 percent. American companies also offer a wider assortment of titanium and nickel alloys, putting them ahead of Japanese competitors in the aerospace market.

The two countries are about even in other areas of metals research, and a good deal of cross investment is taking place. There have been two recent tie-ups in amorphous metals (used as cores in electromagnets and electronic displays). Marko Materials Inc. of Massachusetts has agreed to license its

amorphous metals production technology to Toyo Soda Manufacturing Co., Ltd., which hopes to begin production in Japan and the United States by 1987; and Allied Corp. will begin mass producing a range of amorphous alloys in Japan in conjunction with several Mitsui Group companies. Allied's proprietary process could drastically reduce production costs, gaining the venture a major share of Japan's market. In addition, joint production of nonferrous metals has been set by Nippon Kokan K.K. and Martin Marietta Corp., an agreement opening major new markets to both partners.

There have been some frictions involving U.S. imports of Japanese-made titanium sponge and amorphous metals on grounds of alleged dumping or patent infringement. Competition over supplies of strategic metals is also likely to heat up as more exotic alloys gain wider use. Both governments, however, seem to be handling these matters pragmatically.

Ceramics - It is generally acknowledged that one Japanese company, Kyocera Corp., is the dominant player in the structural ceramics market. By some estimates Kyocera has captured 70 percent of the U.S. market and a majority of Japan's business. This has not prevented new companies from entering the field, however. Kyocera's lead is due to an early start coupled with steady investment and attention to customer needs, not to technological superiority. In fact, according to industry observers, a rough technological parity exists between the two countries at the present time, although heavy investment by Japanese firms could tip the balance in their favor.

There are approximately 250 Japanese companies competing in fine ceramics, all but 60 of which are small, venture capital businesses. Small firms have found the field easy to enter because most ceramic parts are customized products, investment requirements are relatively low, and the products are suited to the organizational structure of small companies. Such firms have targeted a wide range of markets: sensors (Nippon Ceramic Co., Ltd.), optoelectro-ceramics (Yamaju Ceramics Co., Ltd.) and cutting tools (Goei Seisakusho K.K.). These companies are constantly looking over their shoulders, however, at the industrial heavyweights that have joined them -- Toshiba Corp., Toyota Motor Corp., Toray Industries Co., Ltd., Sony Corp. and Ishikawajima-Harima Heavy Industries Co., Ltd., to name just a few.

American behemoths have also jumped into the market and hope to make a big splash. General Electric Co., E.I. duPont de Nemours & Co. and International Business Machines Corp. are all active participants in R&D and commercialization activities. American automakers are intensely interested in ceramics, although they are taking a long-term approach. Small U.S. firms are choosing the joint-venture route, and Japanese companies are ardently courted.

The Japanese start-ups have recently scored some points by announcing several significant developments. The Japan Chemical Engineering Co., Ltd. claims that its new ceramic compound can withstand long exposure to temperatures in excess of 2,000 degrees centigrade, making it a good candidate for use in re-entry vehicles. Tokuyama Soda Co., Ltd. has developed a translucent ceramic composed of aluminum-nitride powder. The product's light-transmitting ability could lead to its use in the booming optoelectronics industry. A ceramic with 14 times the flexibility of existing ceramics has resulted from Clay Burn Ceramics Co., Ltd.'s combination of paper-making

concepts and infrared drying techniques. Ceramic products subject to heavy vibration or stress are likely candidates for the new material.

Competition in this market will only intensify, and public and private observers in both countries are calling for more investment and closer cooperation to stay in the race.

Plastics - Japanese plastic makers have held a slight lead in structural plastics primarily due to demand from automotive and computer manufacturers. Toyota, Honda Motor Co., Ltd. and other companies have been very aggressive in replacing steel body components with plastics. Forty percent of Honda's subcompact CRX is made of plastics. Moreover, the CRX is the first mass-produced car to use a one-piece plastic body. American competitors have nearly erased the gap, though, with General Motor Corp.'s fast-selling plastic-bodied Pontiac Fiero and duPont's full line of plastics specifically designed for automotive uses.

The race to field electroconductive plastics looks like a dead heat at the present time. Many electroconductives have only been produced in the laboratory and manufacturers in both countries are working hard to bring them to market. Because of the high costs of research and production facilities, large chemical companies dominate this race -- Mitsubishi Petrochemical Co., Ltd., Sumitomo Bakelite Co., Ltd. and Showa Denko K.K. in Japan, and duPont, Minnesota Mining & Manufacturing Co., Monsanto Corp. and Dow Chemical Corp. in the United States. The technical problems of developing an easily moldable product are daunting, but the rewards seem worthwhile; demand should skyrocket as microprocessors are incorporated in cars and home appliances.

Competition in other plastics -- membranes, various films and glass substitutes -- is also balanced. The Japanese are catching up in film technology, while the Americans offer equal membrane expertise. Because this area is dominated by large firms, joint ventures are rare, although it is customary for Japanese companies to farm out actual production of newly developed products to a smaller partner.

Fibers - American companies have a visible lead in applications of particular fibers, if not in their manufacture. DuPont's Kevlar polyaramid fiber is critical to many space applications. Its very high tensile strength is vital to casings, hoses and connectors. DuPont is now pushing Kevlar as a replacement for a host of ordinary materials used in machine belts, fasteners, drilling platform rigging and sports equipment. U.S. firms have also been more aggressive than their Japanese competitors in the use of carbon fibers in a wide range of products, even though the Japanese pioneered production and remain the largest producers.

In response to the utility of carbon fibers in a wide range of applications, Japanese companies have narrowed the gap in this area by investing heavily in developing original polyaramid fibers. Joint ventures have played a role in the growth of this market and cross licensing is fairly common. The demands of the electronics and automotive industry should encourage more rapid development, but American firms are not sitting back; they are expected to maintain an edge, albeit a smaller one.

Composites - Japanese and U.S. companies are on an even footing in most segments of this market -- with the exception of metal-ceramics, where Japan has a slight lead, and carbon composites, where U.S. firms have the advantage. Japanese researchers have recently solved some problems with bonding thin metal films to ceramic substrates and this could lead to rapid commercialization of improved semiconductor components. As yet, Ferro-ECA Electronics, a major U.S. maker, has not matched these advances, but the Erie, Pennsylvania company plans to tie up with Nissan Chemical Industries Co., Ltd. to market metal-ceramic and metal paste wares in Japan.

American dominance in aerospace has allowed U.S. carbon composite makers to acquire experience in producing complex parts and tailoring composites to particular needs. Although Japanese companies have the same materials, including electroconductive carbon fibers and ones derived from coal pitch, they have not had the opportunity to apply them. Since Japan's aerospace programs are moving slowly, the opportunities for Japanese firms to catch up remain limited unless they can break into the U.S. market.

Competition in other fiber-reinforced plastics and metals is more balanced because the demands of the Japanese electronics and automotive sectors provide the same stimulus as the U.S. aerospace, electronics and defense industries. Toyota is already employing a silicon carbide-aluminum amalgam for high-wear parts in its engine pistons -- a move being considered by Detroit. Electroconductive or insulating composites are also undergoing rapid development in both countries to meet the demands of the computer industry.

Glass and Crystals - The edge in this category presently lies in Japanese hands. American companies have yet to match their major competitors' expertise at growing large silicon crystals (currently up to eight inches in diameter), or their advances in producing near-perfect crystals of gallium arsenide. While the United States is ahead in optics for astronomy, Japan holds a wide lead in the far larger markets for smaller lenses and automotive glass. Concern over Japan's lead in semiconductor crystal technology has sparked heated efforts by American companies. Still, the gap is not likely to disappear given the resources Japanese companies are devoting to this field.

Coatings and Adhesives - With only minimal information available on this category, it is not clear if any disparity exists between the two countries' competitive positions. Japan appears to have more advanced know-how in industrial paints, particularly for marine usage, and in coatings that absorb electromagnetic radiation. Adhesives manufacturers appear evenly matched, although Japanese companies may be investing more money in research. This category is so new that any evaluation is extremely tentative.

## Governments Off to a Late Start

Direct government involvement in new materials R&D is a relatively recent phenomenon, especially in Japan. For years, however, the U.S. government has exerted a strong indirect influence through its space and defense programs. Government involvement on both sides of the Pacific is likely to balloon, however, given the industry's importance.

Japan - Beyond providing some tax credits for R&D outlays, the government's role in new materials before 1980 was quite small. While it encouraged research in universities, Tokyo did not put funds into targeted new materials projects as it did for electronics. This changed drastically at the start of this decade, however, as the Ministry of International Trade and Industry, the Science and Technology Agency (STA) and Nippon Telegraph and Telephone Public Corp. (NTT) perceived the need for a more organized, government-supported approach.

The Agency for Industrial Science and Technology (AIST) is MITI's main arm for conducting research in new materials. In 1981, AIST initiated a 10-year program to develop basic technologies for future industries, including new materials. With MITI funding, the Engineering Research Association for High-Performance Ceramics, a private group of 15 companies that have hired former MITI personnel, is pursuing the development of high-strength, wear- and corrosion-resistant ceramics. In August 1984, the association agreed to join the United States and West Germany in a project to develop a ceramic car engine -- a goal it had been pursuing independently. Association researchers have announced the development of two heat-resistant ceramics -- a silicon-nitrate version and a silicon-carbide variety -- that can withstand temperatures of 2,200 degrees centigrade for 1,000 hours.

MITI is also pressing ahead in advanced metals technology in its national laboratories. The Electrotechnical Laboratory announced a breakthrough in magnet technology in November 1984 with a heat-resistant magnet using rare earths. MITI has also begun a five-year program to improve the smelting and extraction of rare metals, including gallium, niobium, samarium, yttrium and neodymium. Table 1 shows MITI's fiscal 1985 budget request for new materials projects.

Table 1: MITI's New Materials Budget, FY 1984 and FY 1985

(in millions of yen)

| | Requested FY 1985 | Actual FY 1984 |
|---|---|---|
| Next-Generation Basic Technologies Research | Y35,900 | Y32,600 |
| Other New Materials Research | 17,500 | 13,700 |
| Fine Ceramics R&D | 200 | 200 |
| Basic New Materials Countermeasures | 100 | |
| Industrial Standards Improvement | | |
| Fine Ceramics Standards Survey | 200 | 100 |
| New Materials Standards Survey | 200 | |

Source: Ministry of International Trade and Industry Bulletin, February 1, 1985.

The Science and Technology Agency has mounted an even larger drive in new materials through its network of laboratories and the Japan Research Development Corp. (JRDC). STA and JRDC sponsor the five-year Exploratory Research for Advanced Technology (ERATO) program, with four new materials projects inaugurated in 1981 and budgeted at Y2 billion ($8 million).

- The Hayashi ultra-fine particle project explores the properties of metal particles with diameters of 10 to 2,000 angstroms (one ten-millionth of a meter to two hundred-thousandths of a meter). This project has already discovered that particles of nickel can replace more expensive platinum as a catalyst in many cases; that an alloy of copper and zinc could be useful in the production of methanol fuel; and that super-thin films of gold and germanium exhibit unusual superconductive behavior at different temperatures, with potential applications in electronics.

- The Masumoto amorphous and laminar materials project hopes to develop useful materials based on radically altered molecular structures. It has developed ultra-fine particles of amorphous metals with superior qualities for use in magnetic, catalytic, sensor and super-conductive materials. Ceramic compounds with unusual properties have also been developed, including boron-nitride-silicate and boron-nitride-titanate materials.

- The Ogata fine polymer project has three goals: to synthesize polymers with controllable, high molecular weights; to produce monomolecular polymer films; and to produce polymers with high heat conductivity. The results could lead to super-strong fibers, superior separation membranes and catalysts, excellent thermal conductors for electronic insulators and electroconductive polymers.

- Finally, the Nishizawa perfect crystal project has succeeded in its goal of producing commercially useful defect-free gallium-arsenide crystals. By alternately injecting gallium and arsenine gas into a carefully controlled environment, perfect crystals are grown one molecular lair at a time. It is likely that the project will now work on developing cheaper and more practical methods of growing perfect GaAs crystals and may move to indium-phosphide materials.

STA's laboratories conduct research in other new materials, of which the largest is the National Institute for Research of Inorganic Materials (NIRIM). NIRIM conducts several projects and encourages participation by private industry and universities. Structural ceramics and plastics claim a large share of NIRIM's efforts, although it recently developed a super-conductive metal tape of niobium-aluminum-germanium. The institute has also held a forum on a generalized approach to inorganic material design attended by more than 200 private-sector and government experts.

The Ministry of Education has recently sponsored a broad ceramics program at the Universities of Tokyo, Kyoto, Tohoku and Osaka as well as the Tokyo Institute of Technology. The folowing types of ceramics are being developed: surface active, reactive, electronics and environment-, temperature-, pressure- and opto-sensitive. Although JRDC also funds projects in universities through the provision of interest-free loans, the somewhat feudal university research system hampers research efforts.

NTT's Ibaraki Electrical Communication Laboratory is also involved in the development of electroconductive plastics. Its first breakthrough was the development of a conductive plastic film that can be used as an insulator in computer peripherals and photoelectric and film sensors. NTT's laboratory has

also been instrumental in developing materials for the optoelectronics and semiconductor industries, especially improved photo resists for printed circuit production.

United States - Washington has supported research in new materials for decades under the guise of national defense programs. The production of supersonic aircraft and the exploitation of outer space created demand for high performance materials that attracted the research dollars of major U.S. corporations, giving them a distinct advantage that still exists in some areas. At the start of this decade, U.S. R&D was criticized as being too diffused. It was said that a sharper focus would be necessary to remain internationally competitive. This charge was based on the strong challenges mounted by Japan and Western European countries in computers, aviation and spacecraft. Washington's response was to redirect some of the activities at its 755 laboratories and some of the $15 billion budgeted (fiscal 1984) toward specific new materials projects. In 1983, Congress established the Center for Advanced Materials at the Lawrence Berkeley Laboratory to promote government-industry-university cooperation in new materials R&D.

The center's agenda sports studies of gallium-arsenide crystals, ceramics, alloys and advanced instruments. Ceramics and GaAs crystals are receiving the majority of attention, with close cooperation between private and public researchers. Each project is directed by an advisory board of university and industry scientists, and participating firms are urged to send researchers to the center under an "industrial fellows" program and contribute up to half of the project's funding. The center provides research facilities that are too costly for many individual firms to afford and allows public- and private-sector researchers to interact. Two extremely powerful and expensive electron microscopes are available, and the use of other facilities can also be arranged. The center's director foresees his operating budget rising from $2.9 million in fiscal 1985 (a $0.3 million increase over the previous year) to about $20 million annually in a few years.

A Sandia National Laboratories scientist announced a breakthrough in electroconductive plastics last September, and researchers at the Los Alamos National Laboratory are also engaged in new materials projects. These two labs are particularly notable because they have access to a large number of supercomputers. There are new materials projects underway at other government facilities that are beginning to pay off. For example, the Naval Research Laboratory has developed an epoxy fluoropolymer plastic that could vastly improve the performance of artifical joints and organs.

The National Aeronautics and Space Administration's (NASA) Lewis Research Center continues to promote research in the new materials area, primarily through grants. It awarded a $1.7 million R&D contract to AiResearch Casting Co., a division of Garrett Corp., for ceramic engine materials. The 33-month Phase 1 contract focuses on improving silicon-nitride ceramics for turbine blades and could lead to another $1.7 million 27-month contract. NASA has also been instrumental in developing materials that can withstand the rigors of outer space and the fiery heat of re-entry -- areas with important commercial spinoffs.

The Department of Defense (DOD) also continues to play a key role in expanding the performance of industrial materials. The Defense Advanced

Research Projects Agency (DARPA) and the Navy funded a series of tests of ceramic components in turboprop engines in 1980. Further tests were ordered when the engine, which had 102 ceramic components, produced more power with lower fuel consumption than an all-metal version. The Pentagon's VHSIC (very high speed integrated circuit) program has also yielded commercial gains to participating companies, both in terms of improved materials and increased experience in sub-micron chip technology. Composites figure in DOD's plans as well. The replacement for the jeep will sport a body made of fibreglass-reinforced plastic; the Marine Corps' AV-8B Harrier fighter's wings are carbon fiber composites; the X-29's forward-swept wings were impossible before mature composite technology; and the secret "stealth" aircraft will rely on composites for more than half its components.

The commitment of both governments to new materials is therefore pervasive. More importantly, officials in both countries see this commitment growing rapidly and steadily, particularly in high-risk areas. It seems, for once, that Washington and Tokyo agree that the government must take an active role in funding research and promoting better cooperation in this critical industry.

The New Materials Revolution

New materials will certainly pervade everyday life by the end of this century in ways that scientists are only now beginning to envision. The tidal wave of public and private resources hitting the industry guarantees that it will be a prime arena for U.S.-Japan rivalry. Will competitors in this key area learn to coexist? Several factors must be considered here.

Through joint ventures and cross licensing agreements, there are a significant number of businesses on both sides of the Pacific interested in unfettered competition. Since Washington and Tokyo are following similar policies, the likelihood of friction at the official level is reduced. This similarity could work the other way, however, especially if government policies discriminate against foreign companies or are seen as conferring unfair subsidies. There is also a clear trend in the United States toward trade cases based on infringement of intellectual property rights, an already delicate topic between the two countries and one well suited to the nature of new materials. As Japan slowly moves toward legal protections for intellectual property that are similar to American ones, however, this factor should abate.

While some friction is inevitable, it appears that healthy competition in new materials is likely to characterize the U.S.-Japan relationship. American companies are not awed by the Japanese; rather, they espouse a very aggressive stance. Both sides are investing heavily and show no signs of letting up. Such strong competition can only benefit both sides.

For more information, contact Jon Choy.

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The views expressed in this report are those of the author and do not necessarily represent those of the Japan Economic Institute.

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# JEI REPORT

NO. 9B
March 8, 1985

IN THIS ISSUE:

White House Bucks Decision on Car Exports Back to Japan ..... 1

The Yen: When It Rains, It Pours ..... 2

Japan Seeks to Firm Up Software Development .... 4

Notes ..... 7

## White House Bucks Decision on Car Exports Back to Japan

President Reagan announced March 1 that he will not ask Tokyo to extend restraints on shipments of Japanese-made cars to the United States for a fifth year. The decision, which was predictably greeted with applause in Japan and boos from Chrysler Corp., Ford Motor Co., the United Auto Workers union and congressional supporters of continued auto industry protection, throws the touchy question of export volumes after March 31 back to Tokyo. Japanese government leaders had hoped the Reagan administration would signal how many additional cars could be shipped to the United States without triggering a political backlash, but White House spokesman Marlin Fitzwater emphasized that "there are no hidden deals" with Japan on export numbers. Annual shipments are currently limited to 1,850,000 sedans plus 90,833 station wagons and four-wheel drives and 77,000 cars for Puerto Rico.

Two years of robust U.S. car sales and record-breaking profits in Detroit simplified President Reagan's decision -- at least on economic grounds (see JEI Report No. 8B, March 1, 1985). The only real questions were the timing of the announcement and whether action on the restraint issue would be linked to improved market opportunities in Japan for U.S. exporters of telecommunications equipment, forest products, electronics products and medical

equipment and pharmaceuticals. The president ended up rejecting the option of an explicit trade-off, but his decision to return to free trade in cars was clearly designed to promote progress in the market access talks. "In taking this action," Mr. Reagan said, "I hope we can look forward to reciprocal treatment by Japan concerning the high-level discussions under way between our countries in the weeks and months ahead."

These discussions are not going well, in part because U.S. trade negotiators, frustrated by what they say is Japanese foot-dragging, have resorted to theatrics. Commerce Secretary Malcolm Baldrige told Under Secretary for International Trade Lionel Olmer to skip a scheduled February 26 meeting on proposed standards, testing and certification procedures for telecommunications equipment in the soon-to-be deregulated Japanese market because Tokyo was unwilling to get down to specifics. At talks on wood and paper products the same day, Agriculture Under Secretary for International Affairs and Commodity Programs Daniel Amstutz decided to go for broke, calling on Japan to eliminate "all barriers," especially tariffs, to trade in forest products.

Reagan administration trade policymakers had originally hoped for some signs of broad agreement in each of the four sets of market access talks by the time American and Japanese subcabinet-level officials held their second meeting the week of March 11. These hopes have evaporated. Talks on medical equipment and pharmaceuticals have not even started; the initial round of discussions on electronics was little more than a fishing expedition by the U.S. side, which has yet to formulate a position on this area of trade; and a shouting match erupted in the preliminary forest products talks. Telecommunications equipment might be the one area where progress can be reported -- if only because the draft of the ordinance that will govern Japan's telecommunications market after deregulation was finally completed this past weekend.

Commerce Under Secretary Olmer held his previously scratched meeting with Posts and Telecommunications Vice Minister Moriya Koyama earlier this week. Initial reports from Tokyo indicate that the two delegations made headway on the certification procedures for telecommunications terminals and some related issues, but remained split on the subject of registration standards for large value-added networks.

Susan MacKnight

## The Yen: When It Rains, It Pours

Along with other major currencies, the yen continues to be tossed about in international financial waters by the dollar-driven storm. After a quiet January when the currency moved within a two-yen band, Tokyo exchange markets were hit by buying and selling sprees that pushed the yen up and down over an eight-yen band. Underlying this volatile behavior are the continued short-term attractions of the booming U.S. economy and the abundance of cash-flush Japanese institutions. Japan's net and gross capital outflows have gone from a trickle to a torrent, possibly turning the country into the world's biggest creditor nation.

The dollar's strength pounded European currencies in February; new highs were registered against all currencies despite frequent central bank intervention. The yen, in contrast, emerged bruised but unbowed. After hitting a low of Y263.40=$1.00 at mid-month, it fought its way back up to Y259.50=$1.00 at month's end. Nevertheless, February's average median exchange rate on Tokyo's interbank spot market was a full six yen lower than January's -- Y260.24=$1.00 compared to Y254.18=$1.00. The average daily volume also picked up in the second month of 1985, hitting $1,982 million compared with January's $1,401 million mark.

Bank of Japan governor Satoshi Sumita focused rhetorical and financial attacks on speculators, blasting them in the press and intervening heavily several times in the marketplace. Absent this intervention, the exchange rate would have been extremely volatile. As it was, the yen made some eye-opening moves during the middle of the month. Starting at Y263.40 on February 13, it rose to Y259.90 by the 15th, gained another Y5.30 over the weekend to the month's high of Y254.60=$1.00 on the 18th, but tumbled back to Y260.30 on the 19th.

Central bank intervention is a sensitive topic between the United States and its major trading partners, and both sides pointed to February's events to bolster their positions. Federal Reserve Board chairman Paul Volcker claimed that the dollar's continued gains in the face of heavy intervention by European and Japanese monetary officials showed that not much can be expected of intervention. Other central bank spokesmen argued that the month's events highlighted the importance of strong, coordinated U.S. intervention to shatter speculation in the dollar. Given the Reagan administration's free-market tendencies and the fact that it views the dollar's strength as an asset, heavy intervention is unlikely.

Dollar mania has important effects beyond the trade consequences often recited. As a result of record net capital outflows, Japan is on the verge of becoming the world's largest creditor nation, in stark contrast to the United States, which could become a net debtor nation sometime in 1985. Since registering a $2.3 billion net inflow of long-term capital in 1980 (see JEI Report No. 8B, March 1, 1985), Japan has turned into a major international investor, with net exports of long-term capital jumping from $10 billion in 1981 to $50 billion in 1984 (see table). Coupled with strong direct investments abroad by Japanese companies and a selling wave by foreigners on Japan's stock markets, it is estimated that the country's net external assets almost doubled from $37 billion at the end of 1983 to $70 billion at the close of 1984.

This flood of Japanese funds has raised some concerns among market observers. While the United States certainly benefits from the inflow of capital, the majority of funds have gone into bonds, particularly short-term U.S. government securities. Since these funds remain highly liquid, a massive sellout could trigger a precipitous decline in the dollar's value. While a decline might bring the dollar back into balance with other currencies, a drastic drop could be very disruptive.

Jon Choy

Japan's Long-Term Capital Flows

(in billions of dollars)

| | 1981-1983 | 1984 | 1981-1984 |
|---|---|---|---|
| Puchases of External Assets | $82.7 | $56.9 | $139.6 |
| Direct Investments | 13.1 | 6.0 | 19.1 |
| Trade Credits | 8.6 | 5.1 | 13.7 |
| Loans | 21.4 | 11.9 | 33.3 |
| Securities | 34.5 | 30.8 | 65.3 |
| Others | 5.1 | 3.1 | 8.2 |
| Liabilities to Foreigners | 40.3 | 7.1 | 47.4 |
| Direct Investments | 1.0 | * | 1.0 |
| Trade Credits | * | * | * |
| Loans | -0.4 | -0.1 | -0.5 |
| Securities | 27.9 | -0.2 | 27.7 |
| External Bonds | 11.3 | 7.4 | 18.7 |
| Others | 0.5 | * | 0.5 |
| Net Long-Term Capital | 42.4 | 49.8 | 92.2 |

Source: Bank of Japan

Japan Seeks to Firm Up Software Development

Japan has proven that it can produce top-flight computer hardware, from individual chips to mainframe systems. State-of-the-art software for business and scientific applications, however, has eluded the best efforts of the private sector and the government. In another bid to bring the domestic software industry up to par internationally, the cabinet will submit to the Diet a Ministry of International Trade and Industry (MITI) proposal to revamp the decade-old government support system. While keeping close watch on developments in Tokyo, American programmers view MITI's latest efforts to spur the software industry as only a distant threat to the dominance of U.S. software.

According to the Science and Technology Agency, Japan's software imports in fiscal 1983 jumped 63 percent to 409 transactions, representing 85 percent of all imports of computer-related technology. Because of American dominance in computers, software programs from this country have dominated the Japanese market for years. Microsoft Corp.'s MS-DOS and Digital Research Inc.'s CP/M claim the majority of microcomputer operating systems, while International Business Machines Corp.'s operating systems remain the industry mainframe standard. Japanese mainframe makers have actually played into IBM's hands by building compatible equipment, making IBM software almost mandatory.

Japanese companies have not been dragging their feet, however. According to MITI, there were over 2,000 independent software houses in the country in 1983, racking up sales of $1.5 billion. In addition, major Japanese computer makers had at least ten software "factories" in operation, each